STUDIES ON BIOLOGY AND BIOPESTICIDAL MANAGEMENT OF *SITOPHILUS ZEAMAIS* MOTSCHULSKY (COLEOPTERA: CURCULIONIDAE)

SYNOPSIS OF THE THESIS

Submitted by

Sheetal Sharma

(Registration No. AU22ZOPhD0105)

Under supervision of

Dr. (Mrs.) Neetu Sharma

In Partial Fulfillment of the Requirements for the Degree of

DOCTOR OF PHILOSOPHY

IN

ZOOLOGY

SCHOOL OF BASIC SCIENCES

FACULTY OF EDUCATION, BASIC SCIENCES AND HUMANITIES

ABHILASHI UNIVERSITY

CHAIL-CHOWK, MANDI (H.P.) – 175045

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CERTIFICATE

This is to certify that the synopsis of the thesis titled **"Studies on biology and biopesticidal management of *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae)"** is an original piece of work done by Ms. Sheetal Sharma (Registration No. AU22ZOPhD0105), under my supervision for the degree of Doctor of Philosophy (Zoology) in Abhilashi University, Chail-Chowk Mandi, Himachal Pradesh. It is also certified that this work has not been submitted to any other University for a Ph.D. Degree.

Place: Mandi

Date: 29-06-24

(Signature of Supervisor)

Dr. (Mrs) Neelu Sharma

(Name of the Supervisor)

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A. Introduction

Agriculture has been associated with the production of essential food crops. It is the primary source of livelihood for many people worldwide. It is considered as the backbone of the economic system of a country, and more so for the developing nations. In India, over 70% of the rural households depend on agriculture, contributes about 17% to the total GDP and provides employment to over 60% of the population (Dahal *et al.*, 2020) and thus making it an important sector for economic development. Being the main source of food, world agriculture needs to keep up with the continuing population growth and to develop further and help to alleviate poverty. One of the most important global challenges of our time is meeting future food needs and tackling hunger and malnutrition in the context of climate change and growing population.

Indian Corn, *Zea mays* L. (Poales: Poaceae) is one of the major cereal crops widely cultivated in many dry areas of World including India. Maize is frequently referred as 'Queen of Cereals', because of its extremely high yield potential. Indian corn, also known as maize, is a staple food in many regions, providing essential carbohydrates, proteins, and vitamins. This crop is highly valued not only for its nutritional content but also for its versatility in various culinary applications. Maize is a cross-pollinated crop and its populations comprise freely interbreeding individuals which are heterozygous and heterogeneous. The species is, therefore, adapted to heterozygosity, which is an essential feature of maize cultivars. The cultivars may be open-pollinated (OP) population or hybrid. Hybrid cultivars have the advantage of higher performance and uniformity. Its cultivation supports the livelihoods of millions of farmers and contributes significantly to the agricultural economy. Additionally, Indian corn is used in a variety of industrial products, including biofuels, sweeteners, and biodegradable materials, showcasing its importance beyond just food consumption. In India, maize occupies an area of about 9.72 million hectares with a production of around 28.64 million tonnes.

The *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) maize weevil is one of the most significant pests of stored grains and is mostly accountable for maize damage. Different insect pests, attack on maize during storage and among these pests maize weevil, *S. zeamais* is the most destructive pest (Ebeling, 2002). It is a globally important pest (Bohinc *et al*., 2020), and the farmers have suffered a lot due to the tremendous loss caused by maize weevil (Suleiman *et al*., 2012) in the stored maize. It damages stored grains in the stores by reducing their quality and quantity both (Yang and Tang, 1988).

This pest caused up to 50% losses in stored maize especially when humidity and temperature increase during summer season in the tropical countries (Iqbal *et al*., 1988; Mohammad *et al*., 1988; Ahmad and Ahmad, 2002). In 48 days, 18.3% of losses are predicted to result from an average of two insects per grain. In addition, the significant grain damage may lead to the reduction in nutritional quality, weight, and germination rates of seeds, and it may also affect human health.

The current food security crisis has led to vigorous debate on how best to feed the growing global population. It has been reported that the weevil *S. zeamais* contribute more than 40% grain losses during storage, mainly in developing countries. The commonest method of controlling insects by smallholder farmers is the use of synthetic chemicals. However, indiscriminate use of many synthetic insecticides is associated with manifold health and environmental problems, such as development of resistance in insect pests, high residues in food products, pest resurgence and the destruction of nontarget organisms (Kumar *et al*., 2008). Long term exposure of people to these chemicals could cause acute poisoning and long-term health implications, which may include cancer and reproductive anomalies (WHO, 2018). Plant based products are potential alternatives to synthetic insecticides for pests' control because of their low/non mammalian toxicity, biodegradability, zero residual effect and easy accessibility. More importantly smallholder farmers can easily and cheaply produce these plant extracts for their use.

Most plants are widely used as a source of insecticide compounds and few of them are commercially exported as pesticides. These plants are mainly practiced in two different ways in the fields and stores. Firstly, the active compounds that are responsible for the insecticidal effects are isolated, identified, and chemically synthesized. Secondly, plant crude products of aqueous or organic extracts are used directly (Yang and Tang, 1988). Medicinal plants are excellent candidates in the pursuit of greener, sustainable, more potent, and cost-effective pesticides. The moisture content that rises from insect respiration inside the grain encourages fungal growth, which eventually lowers the grain's quality (Phokwe and Manganyi, 2023). There are a number of medicinal plants with insecticidal properties (Holst *et al*., 2000, Gariba *et al*., 2021). Some plant extracts have growth inhibitory effects on insect and cause the reduction of larval, pupal and adult weight, extended larval and pupal duration, reduced pupal retrieval and reduced rate of adult emergence (Koul *et al*., 2008).

A great number of technologies and use of chemicals against stored grain pests are

available but sole reliance on synthetic chemicals as principal method of pest control has resulted in several problems especially of residual hazards. The government of India is emphasizing to establish national and international buffer stocks of foodgrain with the aim to guard against irregularities in production due to varieties of environmental upheavals circumstances in which storage losses can be minimized (Nookathoti, 2017).

At present residual grain protectants have been employed throughout the World for insect pest control (Arthur 1996). The contact insecticides though provide persistent protection to seeds against pest infestation. The other greater concern is the accumulation of pesticides residues in treated grain and its adverse environmental impact.

In 1957, the All India Coordinated Maize Improvement Project (AICMIP) was established which is a landmark in maize improvement research in India. The establishment of this project greatly organised and strengthened the maize research and development in the country.

There are a number of local medicinal plants known for their insecticidal value (Silassie and Getu, 2009). The application of plant-based product for the management of stored product insects is a prehistoric exercise (Qi and Burkholder, 1981).

B. Literature Review

Maize weevil is red brown in colour and marked on the black four reddish brown spots. Both larvae and adults often feed on the crop and both the stages are responsible for damage. Adult female oviposits within a grain kernel, larvae and pupae complete their life cycle with in the kernel and adult emerges from the kernel. Heavy infestation of adults and larvae of maize weevil causes post-harvest losses ranging from 20-30% on weight basis.

The World Health Organisation (WHO) estimates that plant extracts or their active constituents are used as a folk medicine in traditional therapies of 80% of the World population (WHO, 1993). The use tradition knowledge based on experience of ancient generations may provide valuable clues for developing effective novel bio-pesticidal molecules. Therefore, the present work entitled, “Studies on Biology and Biopesticidal Management of *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae)” has been carried out to evaluate the bio-efficacy of locally available botanicals to minimize the loss of maize grains in field and stores by managing the pest population by ecofriendly way

and means. The literature pertaining to the biology of maize weevil, *S. zeamais* Motsch. and its management with plant products has been reviewed here under.

Throne (1994) studied the life history of maize weevil, *S. zeamais* at 10-40°C and 43-76 percent RH. Survival from egg to adult emergence daily rate of fecundity, duration of development, and number of progenies produced were optimal at 30°C and 75% RH.

Yavoor (2003) observed an incubation period of 5 days and the larval period of 27.25 days on maize grains at temperature of 14 to 34°C and 55 to 88% RH.

Danjumma *et al*. (2009) determined the efficacy of plant materials *Zingiber officinale* against *S. zeamais*, an insect infesting maize. Powders of *Z. officinale* (0.5g-2.0g/50g of grains). were compared to the synthetic conventional insecticide against pest species under laboratory conditions (28-32°C and 65-70% RH.). The result showed that the *Z. officinale* recorded 85-95% mortality. The percent mortality among adults were significantly ($p<0.05$) different from untreated control.

Ojo and Omoloye (2015) evaluated that dry artificial diet pellets prepared with maize, cassava chips and amino acid supplements for mass culture of *S. zeamais*. Studies showed that it is possible to rear pest species on artificial diet pellet prepared and formulated from locally sourced Nigerian crops and is feasible for the mass culture of *S. zeamais*.

Suleiman *et al.* (2012) evaluated the plant powders prepared from five plant species under constant condition at 30±2°C and 60-65% RH. for their ability to protect sorghum grains against *S. zeamais* in storage. All the plant powders showed significant ($p<0.05$) adult mortality of *S. zeamais* with weevil perforation index of <50.00.

Gemu *et al.* (2013) studied the efficacy of some locally available agricultural wastes including sawdust, coffee husk and wood ash at different concentrations against *Sitophilus zeamais* and *Sitotroga cerealella* in laboratory condition and experiments were laid out in completely randomized design (CRD) in three replications. Wood ash and coffee husk at higher rates were more effective in controlling the pests. Sawdust at all dosages was not different from the untreated control in controlling *S. zeamais*. However, sawdust at some dosages showed superior performance against *S. cerealella*.

Devi *et al.* (2014) were carried out effect of botanical plant powder extracts on the control of rice weevil. The botanical powder *Azardirachta indica* were tested for their efficacy on mortality, rate of adult emergence and grain damage against rice weevil. The result shows that the mortality rate of *A. indica* was 70.74%. The plant powder of *A. indica* was found

highly effective for the adult emergence and reduction in grain damage.

Mathias *et al.* (2015) studied the egg laying behaviour of the maize weevil, *S. zeamais* in uninfested and previously infested maize grains. The number of progenies produced was higher in conditioned maize. The highest and lowest number of adults emerged from conditioned and uninfested maize. *S. zeamais* individuals were significantly more attracted to conditioned grain as compared to uninfested grains. The number of eggs per grain showed a contiguous distribution because female laid additional eggs on grains already infested with more than one egg. The result of this study indicated the possible role of the aggregation pheromone, intraspecific competition and egg marking in the observed egg- laying behaviour pattern of this pest species.

Bulto *et al*. (2017) evaluated botanical powder of Eucalyptus globules at varying concentrations against maize weevil under laboratory condition. It caused mortality rate at 30% and 50% and being safer to the environment should be recommended for future usage.

Lal *et al.* (2017) studied the importance of different plant products (botanicals) against storage insect-pests of seed grains. Among various biotic and abiotic factors which determine fate of grains during storage, insect pests are of economic importance as they cause significant losses. By reducing and eliminating the insect-pest population while storage the rising demands of the increasing population of the world can be fulfilled. Exploiting synthetic pesticides to manage different insect-pests could be hazardous to environment and ecosystem in various ways such as natural enemies, insect resistance and resurgence problem. The botanicals leaves proved to be a better option to control insect pests including storage pests without affecting the quality of grains or seeds and without harming our ecosystem or environment.

Cosmas *et al.* (2018) evaluated the use of botanical pesticides in controlling *S. zeamais* on stored grain in a laboratory condition. The result showed that the *Epuraea tereticon* is recorded highest mortalities (at dose of 20g/200 grain) and showed potential in controlling *S. zeamais*. Knowing the developmental status of stored grains insects especially the immature stages hidden in cereal kernels such as *S. zeamais* could be helpful in early monitoring and effectively controlling such pests.

Mallah *et al.* (2018) studied the effectiveness of some locally available botanicals for eco-friendly management of storage pests. The botanicals significantly affected weevil

mortality and grain weight loss as compared to untreated check, but were not as effective as celphos. *Bojho rhizome* powder 5% was significantly more effective among botanicals with least average weight loss of 1.19% and also with highest weevil mortality rate followed by neem and titepati with their respective highest concentrations.

Regmi *et al.* (2018) studied that the efficacy of botanicals against maize weevil in stored under laboratory conditions. The lemon grass was significantly more effective ($p<0.05$) compared to other treatments and control.

Okram and Hath (2019) conducted research on "Biology of *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) on stored rice grains during different seasons in Terai Agro-Ecology of West Bengal" and Laboratory experiments were carried out to study the biology of *Sitophilus oryzae* on stored rice grains in different seasons during 2016-17. The results of the laboratory experiments revealed that the duration of various developmental stages i.e. incubation, larval, pupal period and adult longevity varied from one season to another season. Total life cycle of male with food (96.09±3.81), without food (50.35±1.85) and total life cycle of female with food (114.61±2.98), without food (51.84±1.56) were also longest during February when the temperature and relative humidity ranges from 12.39°C to 27.89°C and 58.33 to 88.81% R.H. respectively. The longevity of adult female was always higher than the males irrespective of season and food.

Mehta and Kumar (2020) studied that influence of different plant powders namely *Ocimum basilicum* (basil), *Azardirachta indica* (neem) and Eucalyptus citriodora (eucalyptus) as grain protectants on rice weevil. The result showed that the powder of A. indica were highly effective than that of *O. basilicum* and *E. citriodora*.

Riaz *et al.* (2109) reported the entomocidal effectiveness of some indigenous botanical powder, including *Azardirachta indica* (neem), *Curcuma longa* (turmeric) against maize weevil cultured on maize grains in the laboratory condition. (27±2°C and 65±5% RH) A. indica showed the maximum mean cumulative adult mortality of 91% while *C. longa* recorded 76.66% mortality of adult maize weevil. It is concluded that the tested plant powders of *A. indica* and *C. longa* could be utilized for the management of maize weevil.

Mehta *et al.* (2021) studied the biological parameters and orientation of *S. oryzae* towards

wheat cultivar HPW 236 and mixed grains of different cultivars. The incubation, larval and pupal period and life cycle of *S. oryzae* was longer when fed on mixed grains. They evaluated the quantitative losses caused by *S. oryzae* in different cultivars.

Azeez and Oke (2022) studied the bioactivity of turmeric leaf powder against maize storage pest, *S. zeamais* at 28±2°C and relative humidity 65±5% in the laboratory. The leaf powder of *Curcuma longa* (Turmeric) as used against *S. zeamais*. 0.25% contributions. Result showed that the mortality following treatment of turmeric was 82.50%. The plant powder also reduced weight loss in the stored maize seeds as compared to the control.

Kumari *et al.* (2022) worked on studies on the biology of maize weevil under controlled condition of temperature and humidity in BOD Incubator with three replications. The incubation period ranged from 7 to 10 days larval period ranged from 31 to 38 days and the total pupal period ranged from 9 to 14 days. The total life cycle from egg to adult was 87 to 102 days in males and 98 to 109 days in females during November 2021 to January 2022 the temperature and relative humidity were from 30°C and 60-75% RH respectively.

Achimon *et al.* (2022) explored the insecticidal effect of EOs against the maize weevil through different types of contact methodologies. Still, it should be considered that the different routes of penetration are not always clearly demarcated. However, regardless of the application method, the meta-analyses conducted in the present study showed that EOs have great potential to be used as bioinsecticides against *S. zeamais*. The species *Carum carvi*, *Salvia umbratica*, *Ilicium difengpi*, *Periploca sepium*, *Cephalotaxus sinensis*, *Murraya exotica*, *Rhododendron anthopogonoides*, *Ruta graveolens*, *Eucalyptus viminalis*, *Ocotea odorifera*, *Eucalyptus globulus*, *Eucalyptus dunnii*, *Anethum graveolens*, *Ilicium verum*, *Cryptocarya alba*, *Azadirachta indica*, *Chenopodium ambrosioides*, *Cupressus semperivens*, *Schinus molle*, *Piper hispidinervum*, *Mentha longifolia*, and *Croton pulegiodorus* showed LC_{50} or LD_{50} values lower than the global means, indicating good insecticidal properties.

Sackey *et al.* (2023) conducted a survey in the Southern part of Volta region in Ghana collected data on plant species used as maize protectants. A total of eleven plant species were obtained. Seven out of the eleven were selected based on their availability and accessibility including lemon grass (*Cymbopogon citratus*), basil (*Ocimum basilicum*), acheampong leaves (*Chromolaena odorata*), garlic (*Allium sativum*), Africa scent leaf

(*Ocimum gratissimum*), guava leaves (*Psidium guajava*), onion (*Allium cepa*) for preliminary screening. Four most efficacious species (*Cymbopogon citratus*, *Psidium guajava*, *Ocimum basilicum* and *Ocimum gratissimum*) were selected for further work in the laboratory at 28±2°C, 65% RH and 12D:12L against *S. zeamais*.

In conclusion, while specific research on medicinal plant extracts may be limited but knowledge and resources offer valuable starting points for further investigation. By combining traditional knowledge with scientific research, India can contribute significantly to develop eco-friendly and sustainable solutions for controlling *S. zeamais* and other grain storage pests.

C. Research Gap

A critical research gap in the study of *S. zeamais* lies in the integration of indigenous knowledge into pest management strategies. While conventional approaches dominate the literature, there is scant attention given to the rich repository of traditional practices used by local communities to mitigate weevil infestations. Integrating indigenous knowledge could be culturally relevant and sustainable solutions, yet this remains an underexplored area. Negeri *et al.* (2019) in his study highlights the farmers indigenous knowledge and management of insect pests in maize, emphasizing the need for further research to bridge this gap and enhance the effectiveness of pest control strategies.

D. Objectives

The present study has been planned with following objectives:

1. To study the comparative life history of *Sitophilus zeamais* on different cultivars of *Zea mays*.
2. To evaluate the resistance and susceptibility of the cultivars used against the pest species.
3. To screen out the locally available plant species based on traditional knowledge for the management of the pest species.
4. To evaluate the bio-pesticidal efficacy of the four prominent plant species by using different concentrations of powder formulations and wet extracts in different solvents.

E. Research Methodology

To achieve the planned objectives, the following study area and methodology will be used:

1. Study of comparative life history of S. *zeamais* on different cultivars of Zea mays

- Several cultivars of *Zeamais* varieties, will be selected for the study and procured from research stations:
    - CSK Himachal Pradesh Krishi Vishwavidyalaya Palampur, District Kangra, H.P.
    - ICAR-IIMR, Ludhiana, Punjab.
    - ICAR-NBPGR RS, Phagli, Shimla.
- Maize weevil will be reared on normal environmental conditions to ensure consistent development conditions.
- Life history traits such as developmental time from egg to adult, fecundity (number of eggs laid), mortality rate, and adult longevity will be recorded for each maize cultivar.
- Statistical tools will be used to compare the life history traits of pest across the different maize cultivars, identifying any significant differences.

2. Evaluation of resistance and susceptibility of the cultivars against pest species.

- Each maize cultivar will be exposed to a controlled number of S. *zeamais* individuals in a consistent manner.
- The extent of damage caused by the pest, such as weight loss of grains and reduction in grain quality, will be evaluated. The survival rate of the pest on each cultivar will also be recorded.
- Specific resistance indicators such as antibiosis (adverse effect on pest biology), antixenosis (pest deterrence), and tolerance (ability to withstand damage) will be identified and measured.
- The resistance and susceptibility levels of the cultivars will be compared using statistical methods to determine which cultivars are more resistant or susceptible to the pest.

3. Screening of locally available plant species based on traditional knowledge for pest management

- Surveys will be conducted to gather information on plant species traditionally used in the region for pest management.
- The plant species mentioned in traditional practices will be collected and accurately identified.
- Initial bioassays will be performed to test the efficacy of these plant species against pest species.
- Traditional knowledge and preliminary findings will be documented for future reference.

4. Evaluation of Bio-pesticidal Efficacy of Selected Plant Species

- Four plant species showing the most promise based on preliminary screening will be selected for further evaluation.
- Powders will be prepared from dried plant materials and wet extracts will be prepared using different solvents such as water, ethanol, methanol, and acetone at different concentrations (e.g., 1, 2, 5, 10%). (Sharma and Shukla, 2011)
- These formulations will be applied to infested maize grains in the culture and observations will be monitored for Mortality rates, feeding deterrence, and reproductive inhibition of pest.
- The data will be analyzed to determine the efficacy of each formulation and concentration, identifying the most effective treatments.

This methodology is designed to comprehensively assess the resistance and susceptibility of maize grains against *S. zeamais* and exploration of traditional plant-based pest management options, and evaluate the bio-pesticidal potential of selected plant species.

F. Research Plan Schedule

A detailed research plan schedule for a two-year study on the biology and biopesticidal management of S. *zeamais* is projected below:

Year 1

Quarter 1 (Months 1-3):

- **Literature Review and Initial Planning:**
  - Conduct a comprehensive literature review on S. *zeamais*, maize cultivars, and traditional pest management practices.
  - Develop detailed research protocols and experimental designs.
  - Identify and procure necessary equipment and materials.
- **Selection and Preparation of Maize Cultivars:**
  - Select different cultivars of Zea mays for the study.
  - Source and prepare maize seeds for planting.

Quarter 2 (Months 4-6):

- **Planting and Cultivating Maize:**
  - Plant maize seeds in controlled environments to ensure uniform growth.
  - Maintain the maize plants under optimal growing conditions.
- **Collection and Rearing of *S. zeamais*:**
  - Collect *S. zeamais* specimens from local sources.
  - Establish and maintain a laboratory colony of *S. zeamais* under controlled conditions.

Quarter 3 (Months 7-9):

- **Life History Studies:**
  - Conduct experiments to observe and record the life history traits of *S. zeamais* on different maize cultivars.
  - Monitor and document developmental stages, fecundity, mortality rates, and longevity.

Quarter 4 (Months 10-12):

- **Data Analysis for Life History Studies:**
  - Analyze data collected from life history experiments.

- Identify significant differences in the biological traits of *S. zeamais* across different maize cultivars.

- **Preparation for Resistance and Susceptibility Testing:**
  - Set up infestation experiments to evaluate resistance and susceptibility of maize cultivars.

Year 2

Quarter 5 (Months 13-15):

- **Resistance and Susceptibility Testing:**
  - Expose different maize cultivars to controlled infestations of *S. zeamais*.
  - Assess the extent of damage, survival rate of the pests, and specific resistance indicators.

Quarter 6 (Months 16-18):

- **Screening of Traditional Plant Species:**
  - Conduct surveys to gather information on locally available plant species used in traditional pest management.
  - Collect and identify these plant species.
- **Preliminary Bioassays:**
  - Perform initial bioassays to test the efficacy of collected plant species against *S. zeamais*.

Quarter 7 (Months 19-21):

- **Selection and Preparation of Bio-pesticidal Formulations:**
  - Select the 4-5 most promising plant species based on preliminary screening.
  - Prepare powder formulations and wet extracts using various solvents and different concentrations.

Quarter 8 (Months 22-24):

- **Bio-pesticidal Efficacy Evaluation:**

- Conduct bioassays to evaluate the efficacy of different formulations and concentrations against *S. zeamais*.
- Monitor mortality rates, feeding deterrence, and reproductive inhibition.

- **Data Analysis and Reporting:**
  - Analyze the data from bio-pesticidal efficacy experiments.
  - Compile and interpret the overall findings of the study.
  - Prepare and submit final reports, manuscripts for publication, and presentations for dissemination of results.

This schedule outlines a comprehensive plan to achieve the research objectives within two years, ensuring thorough investigation and robust results.

G. Significance of The Study:

The proposed study on the biology and biopesticidal management of *S. zeamais* holds significant importance for several reasons:

1. **Enhanced understanding of pest biology:** By studying the life history traits of *S. zeamais* on different cultivars of maize, we gain a deeper understanding of the pest's development, reproduction, and survival mechanisms. This knowledge is crucial for developing effective pest management strategies.
2. **Identification of resistant maize cultivars:** Evaluating the resistance and susceptibility of various maize cultivars helps identify those that are less prone to infestation by *S. zeamais*. This can lead to the cultivation of more resilient crops, reducing reliance on chemical pesticides and lowering production costs.
3. **Promotion of sustainable pest management:** By screening locally available plant species based on traditional knowledge for their pest management properties, the study promotes the use of sustainable and environmentally friendly pest control methods. Traditional knowledge often encompasses eco-friendly practices that have been refined over generations.
4. **Economic Benefits by reduction of post-harvest losses:** *S. zeamais* is a major pest of stored maize, causing significant post-harvest losses. Effective management of this pest can reduce these losses, ensuring better food security and utilizing resistant

cultivars and bio-pesticides can decrease the need for expensive chemical treatments which results to economic benefits for farmers.

5. **Conservation of biodiversity:** The use of plant-based bio-pesticides can minimize the negative impacts of chemical pesticides on non-target organisms and overall biodiversity. This aligns with global efforts to promote biodiversity conservation in agricultural practices.

In summary, this study is significant as it addresses both the biological understanding and practical management of *S. zeamais*, offering benefits that range from improved crop resilience and reduced pest-related losses to the promotion of sustainable agricultural practices.

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